Fig. 40 is a graph of the optical response for a cavity which appears blue.

Fig. 41 is a graph of the optical response for a cavity which appears green.

Fig. 42 is a graph of the optical response for a cavity which appears red.

Fig. 43 is a graph of the optical response for a cavity which appears white.

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Fig. 44 is a perspective view of a fragment of a reflective flat panel display.

Figs. 45A, 45B, 45C, and 45D are perspective views of different spacers during fabrication.

Figs. 46A, 46B, 46C, and 46D are also perspective views of different spacers during fabrication.

Figs 47A, 47B, 47C, and 47D are top views of a static graphic image. --

Insert the following paragraphs beginning at page 41, line 17:

-- Any thin film, medium, or substrate (which can be considered a thick film) can be defined in terms of a characteristic optical admittance. By considering only the reflectance, the operation of a thin film can be studied by treating it as an admittance transformer. That is, a think film or combination of thin films (the transformer) can alter the characteristic admittance of another thin film or substrate (the transformed film) upon which it is deposited. In this fashion a normally reflective film or substrate may have it's characteristic admittance altered (i.e., transformed) in such a way that its reflectivity is enhanced and/or degraded by the deposition of, or contact with, a transformer. In general there is always reflection at the interface between any combination of films, mediums, or substrates. The closer the admittance of the two, the lower the reflectance at the interface, to the point where the reflectance is zero when the admittances are matched.

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Referring to Fig. 36, reflector 3600 (the transformed film) is separated from induced absorber 3605 (the transformer), comprising films 3604, 3606, and 3608, by variable thickness spacer 3602. Incident medium 3610 bounds the other side of induced absorber 3605. Each of these thin films is micromachined in a fashion described in the parent patent application. Induced absorber 3605 performs two functions. The first is to match the admittances of reflector 3600 and incident medium 3610. This is accomplished via matching layer 3608, which is used to transform the admittance of

absorber 3606 to that of the incident medium 3610, and via matching layer 3604, which is used to transform the admittance of reflector 3600 to that of absorber 3606. The second function is the absorption of light. This is accomplished using absorber 3606, which performs the function of attenuating light which is incident upon it through the medium, as well as light which is incident upon it from the reflector.

The ability to alter the thickness T of spacer 3602 allows the optical characteristics of the entire structure to be modified. Referring to Fig. 37, pixel 3700 is shown in the driven state and pixel 3702 in the undriven state. In this case induced absorber 3706 (the transformer) resides on substrate 3704 and reflector 3708 (the transformed film) is a self-supporting structure. Application of a voltage causes reflector 3708 to come into contact or close proximity with induced absorber 3706. Proper selection of materials and thickness will result in a complete transformation of the admittance of reflector 3708 to that of substrate 3704. Consequently, a range of frequencies of light 3705, which is incident through substrate 3704, will be significantly absorbed by the pixel. With no voltage applied, reflector 3708 returns to its normal structural state which changes the relative admittances of the reflector and the substrate. In this state (pixel 3702) the cavity behaves more like a resonant reflector, strongly reflecting certain frequencies while strongly absorbing others.

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Proper selection of materials thus allows for the fabrication of pixels which can switch from reflecting any color (or combination of colors) to absorbing (e.g., blue to black), or from reflecting any color combination to any other color (e.g., white to red). Referring to Fig. 38, in a specific pixel design, substrate 3802 is glass, matching layer 3804 is a film of zirconium dioxide which is 54.46 nm thick, absorber 3806 is a tungsten film 14.49 nm thick, matching layer 3805 is a film of silicon dioxide 50 nm thick, spacer 3800 is air, and reflector 3810 is a film of silver at least 50 nm thick. Referring to Fig. 39, the optical response of the pixel is shown in the driven state, i.e., when reflector 3810 is in contact with matching layer 3808 resulting in a broad state of induced absorption. Referring to Figs. 40-43, the different color pixels are shown in respective undriven states which correspond to the reflection of blue, green, red, and white light, respectively.

These responses correspond to undriven spacer thicknesses of 325, 435, 230, and 700 nm, respectively.

Referring to Fig. 44, a section of full color reflective flat panel display 4400 includes three kinds of pixels, R, G, and B. Each kind differs from the others only in the size of the undriven spacer which is determined during manufacture as described in the parent patent application. Induced absorber 4402 resides on substrate 4406, and reflector 4410 is self-supporting. Monolithic backplate 4404 provides a hermitic seal and can consist a thick organic or inorganic film. Alternatively, the backplate may consist of a separate piece, such as glass, which has been aligned and bonded to the substrate. Electrodes may reside on this backplate so that the electromechanical performance of the pixels may be modified. Incident light 4412 is transmitted through optical compensation mechanism 4408 and substrate 4406 where it is selectively reflected or absorbed by a pixel. The display may be controlled and driven by circuitry of the kind described in the parent patent application.

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Optical compensation mechanism 4408 serves two functions in this display. The first is that of mitigating or eliminating the shift in reflected color with respect to the angle of incidence. This is a characteristic of all interference films and can be compensated for by using films with specifically tailored refractive indices or holographic properties, as well as films containing micro-optics; other ways may also be possible. The second function is to supply a supplemental frontlighting source. In this way, additional light can be added to the front of the display when ambient lighting conditions have significantly diminished thus allowing the display to perform in conditions ranging from intense brightness to total darkness. Such a frontlight could be fabricated using patterned organic emitters or edge lighting source coupled to a micro-optic array within the optical compensation film; other ways may also be possible.

The general process for fabrication of the devices is set forth in the parent patent application. Additional details of two alternative ways to fabricate spacers with different sizes are as follows; other ways may also be possible.

Both alternative processes involve the iterative deposition and patterning of a sacrificial spacer material which, in the final step of the larger process is, etched away to form an air-gap.

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Referring to Fig. 45A, substrate 4500 is shown with induced absorber 4502 already deposited and photoresist 4504 deposited and patterned. Induced absorber 4502 is deposited using any number of techniques for think film deposition including sputtering and e-beam deposition. The photoresist is deposited via spinning, and patterned by overexposure to produce a natural overhang resulting in a stencil. The result is that it may be used to pattern subsequently deposited materials using a procedure known as lift-off. Referring to Fig. 45B, spacer material 4506 has been deposited, resulting in excess spacer material 4508 on top of the stencil. Referring to Fig. 45C, the stencil along with the excess spacer material have been lifted off by immersing the device in a bath of solvent such as acetone and agitating it with ultrasound. Referring to Fig. 45D, the process has begun again with new photoresist 4510 having been deposited patterned in a fashion such that new spacer 4512 is deposited adjacent to the old spacer 4506. Repeating the process once more results in spacers with three different thicknesses. Referring to Fig. 45D, the process has begun again with new photoresist 4510 having been deposited patterned in a fashion such that new spacer 4512, with a different thickness, is deposited adjacent to the old spacer 4506.

Referring to Fig. 46A, substrate 4600 is shown with induced absorber 4602 already deposited. Spacer materials 4604, 4606, and 4608 have also been deposited and patterned by virtue of lift-off stencil 4610. The spacer materials have a thickness corresponding to the maximum of the three thicknesses required for the pixels. Referring to Fig. 46B, the stencil along with the excess material has been lifted off and new photoresist 4612 has been deposited and patterned such that spacer 4604 has been left exposed. Referring to Fig. 46C, spacer material 4604 has been etched back via one of a number of techniques which include wet chemical etching, and reactive ion etching. Only a portion of the required spacer material is etched away, with the remainder to be etched in a subsequent etch step. Photoresist 4612 is subsequently removed using a similar technique. Referring to Fig. 46D, new photoresist 4614 has been deposited and

patterned exposing spacers 4604 and 4606. The entire etch of spacer 4606 is performed in this step, and the etch of spacer 4604 is completed. Photoresist 4614 is subsequently removed and the process is complete.

Other embodiments are within the scope of the following claims.

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For example, the spacer material need not ultimately be etched away but may remain instead a part of the finished device. In this fashion, and using the previously described patterning techniques, arbitrary patterns may be fabricated instead of arrays of simple pixels. Full color static graphical images may thus be rendered in a method which is analogous to a conventional printing process. In conventional printing, an image is broken up into color separations which are basically monochrome graphical subsets of the image, which correspond to the different colors represented, i.e., a red separation, a blue separation, a green separation, and a black separation. The full-color image is produced by printing each separation using a different colored ink on the same area.

Alternatively, in a process which we will call "Iridescent Printing", the different separations are composed of layers of thin films which correspond to the IMod design described here and those in the referenced patent. Patterning or printing a combination of colors or separations on the same area, allows for brilliant full-color images to be produced.

Referring to Fig. 47A, a square substrate is shown with area 4700 representing the portion of the substrate which has been patterned with a thin film stack optimized for black. Referring to Fig. 47B, the substrate has been subsequently patterned with a thin film stack optimized for red in area 4702. Referring to Fig. 47C, the substrate has been subsequently patterned with a thin film stack optimized for green in area 4704. Referring to Fig. 47D, the substrate has been subsequently patterned with a think film stack optimized for blue in area 4706.

Alternatively, a simpler process can be obtained if only the induced absorber design is used. In this process, the entire substrate is first coated with the induced absorber stack. Subsequent steps are then used to pattern the spacer material only, using the aforementioned techniques. After the desired spacers, i.e., colors are defined, a final deposition of a reflector is performed.